Biomechanical Evaluation of the Effect of Intramedullary Fibular Graft in Proximal Humeral Fractures

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Proksimal Humerus Kırıklarında İntramedüller Fibula Greftinin Biyomekanik Etkisi

The Effect of Fibular Graft in Proximal Humeral Fracture

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Özet

Amaç: Bu çalışmanın amacı; iki parçalı proksimal humerus kırık modellerinde, intramedüller fibula greftinin etkisini biyomekanik olarak araştırmaktır. Aynı zamanda iki farklı pozisyonda uygulanan intramedüller fibula greftinin stabilite üzerine olan etkisi de araştırılmıştır. Gereç ve Yöntem: Toplam 21 boyun kırığı olan iki parçalı proksimal humerus modeli rastgele 3 gruba ayrıldı. Tüm kırık modelleri anatomik kilitli plak ve 3.5mm kilitli vida ile fikse edildi. İntrameduller fibula; Grup1'de humerusun uzun aksına parallel yerleştirilirken, Grup2'de humerus boynunun kalkarını ve medialini destekleyecek şekilde yaklaşık 135 derecelik açıda yerleştirildi. Kontrol grubunda fibula kullanılmadı. Tüm modeller erken aktif abduksiyonda meydana gelen primer aksiyel yüklenmeyi ve makasla kuvvetini taklit edecek şekilde 20 derece abduksiyonda uniaksiyel elektromekanik test cihazına yerleştildi. Yüklenme değerleri ile bükülme dirençleri ölçüldü. Bulgular: Grupların yüklenme değerleri ve bükülme dirençleri arasında istatiksel anlamlı fark bulunmadı. Tartışma: Bu sonuçlar medial kolonun anatomik redüksiyonu sonrası kilitli plak ve vida ile fikse edilen iki parçalı humerus proksimal uç kırıklarında fibula varlığı ya da pozisyonunun stabiliteye ek pozitif etki sağlamadığı yönünde yorumlanmıştır. Sonuç olarak; anatomik redüksiyonun elde edildiği proksimal humerus kırıklarında intramedüller fibula gerekli değildir. Bu olgularda kilitli plak ve vida ile fiksasyon yeterlidir. Her nekadar humerus proksimal uç kırıklarında intramedüller fibula popüler bir uygulama olsada kullanımı medial kolonun restore edilemediği osteoporotik unstabil kırıklarla sınırlı kalmalıdır.

Anahtar Kelimeler

Fibula Grefti; Proksimal Humerus Kırıkları; Biyomekanik Etki

Abstract

Aim: The aim of this study is to investigate the biomechanical effect of intramedullary fibular grafts in two-part proximal humeral fracture models. We also investigated two different positions of an intramedullary fibular graft in terms of fracture stability. Material and Method: A total of 21 two-part humeral neck fracture models were randomly separated into 3 groups. All fracture models were fixed with anatomic locking plates and 3.5mm locking screws. An intramedullary fibular graft was placed parallel to the long axis of the humerus in group I and at an approximately 135 degree angle, so as to support the calcar and medial column of the humeral neck, in group II. No fibular graft was used in the control group. All models were tested with a uniaxial electromechanic device at 20 degrees abduction that mimics the primary axial loads and shear forces with early active abduction. Values of loading and stiffness were measured. Results: No statistically significant difference was found for loading and stiffness values between groups. Discussion: These results were interpreted to mean that the presence or positioning of a fibular graft makes no additional contribution to the stability of two-part proximal humeral neck fractures with an anatomically reduced medial column fixed by a locking plate and screws. In conclusion, it is not necessary to utilize an intramedullary fibular graft in proximal humerus fractures when anatomic reduction is obtained. An unaccompanied locking plate and screws are adequate for these cases. Although using a fibular graft in proximal humerus fractures is a popular technique, it should be reserved for unstable osteoporotic fractures in which the medial column cannot be reduced.

Keywords

Fibular Graft; Proximal Humerus Fractures; Biomechanical Effect

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Introduction

Proximal humeral fractures are relatively common, and treatment of these fractures is difficult. Many of these fractures can be treated with the use of operative stabilization. Operative stabilization aims to restore the proximal humeral anatomy, and it optimizes and improves functional outcome.

Various internal fixation methods, such as T-plates, cloverleaf plates, tension-band wiring, intramedullary nails, and locking plates are currently used for the treatment of proximal humeral fractures [1]. Locking plate fixation provides angular stability and improves pull-out strength. The potential complications of using a locking plate are varus collapse of the fracture and screw perforation of the articular surface [2].

The mechanical support of the medial region is important, because without this support complications increase [3]. Intramedullary fibular allograft is used for restoration of the mechanical integrity of the medial column [4].

Fibular allograft has several advantages and drawbacks [4]. The diameter of the fibula is ideal and large enough for intramedullary placement and for providing support to the medial column [4]. Limited supply, high cost, and infection risk of these cadaveric allografts are the drawbacks [4].

The aim of this study is to investigate the biomechanical effect of intramedullary fibular grafts on the stability of two-part proximal humerus fractures with an anatomically reduced medial column using a locking plate and screws. We also compared the effects on stability of two differently placed intramedullary fibular grafts.

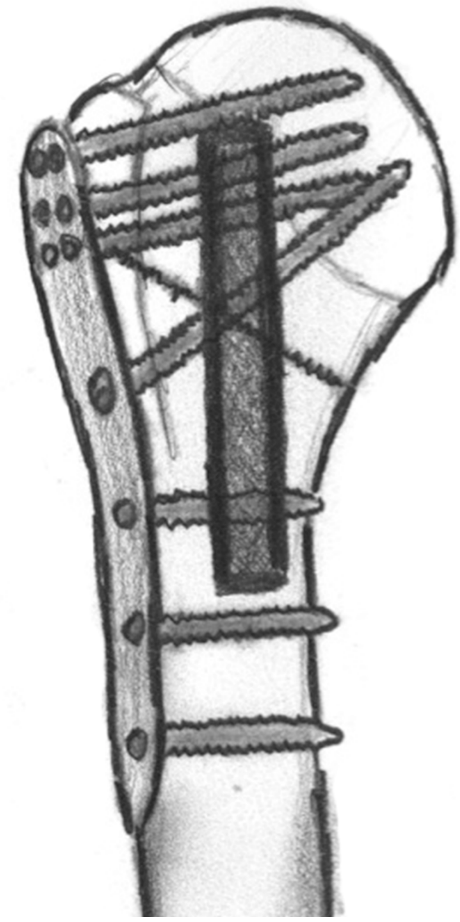

Figure 1. The model of group I

Material and Method

A total of 21 foam/cortical shell left humeri with two-part proximal neck fracture (model 1028-64; Sawbones Europe AB, Malmö, Sweden) and 14 foam/cortical shell left fibula (model 1127; Sawbones Europe AB, Malmö, Sweden) were obtained and randomly divided into 3 groups, each with 7 humerus fracture models. We prepared two fracture groups in which fixation was augmented with intramedullary fibula and one control group without fibula. All fracture models were fixated by an anatomical locking plate and locked 3.5 mm screws (Miss LC proximal humerus plate, TST, Istanbul, Turkey) in a conventional mode. Locked screw lengths were the same in all groups: from proximal to distal 2x40 mm, 2x45 mm, 2x50 mm (calcar), 3x30 mm (shaft). In group I intramedullary fibula (6 cm) was placed as described by Gardner et al. [4] (Figure 1). In the literature, proximal humeral neck-shaft angles have been reported to be approximately 135 degrees [5]. Therefore in group II intramedullary fibula (6 cm) was placed to support calcar and medial portion of the humeral head with an angle of approximately 135 degrees (Figure 2). In the control group no fibula was used. Each construct was mounted in a custom made apparatus at a 20 degree abduction angle following the model established by Koval et al. [6] (Figure 3). This model simulates primarily axial and shear load during a motion analogous to that seen in early active abduction [7]. All constructs were then loaded with a uniaxial electromechanical testing device (Shimadzu 5kN AG-X, Shimadzu, Japan). The load was applied to the constructs until failure with a displacement rate of 10 cm/min [8]. Displacements between fracture ends were measured with a 2-CCD

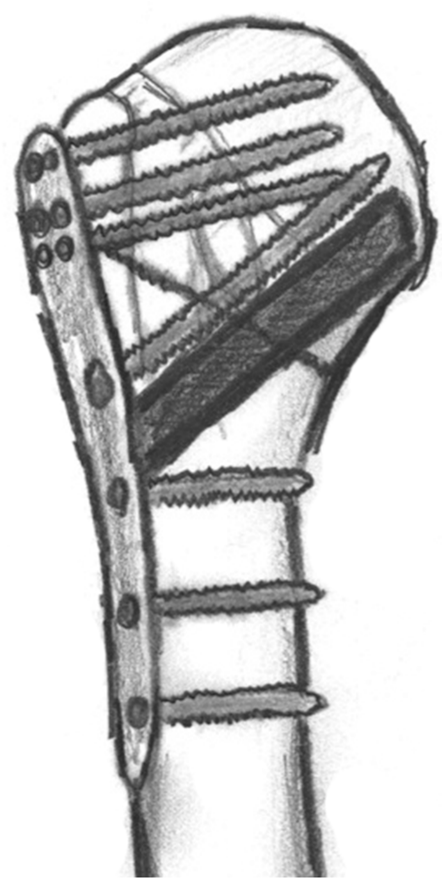

Figure 2. The model of group II

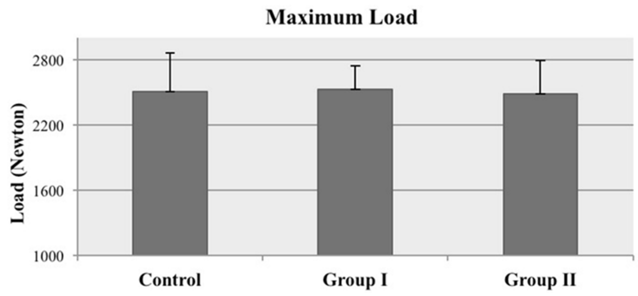

Figure 3. Testing model

camera (Non-contact video extensometer, DVE-101/201, Shimadzu, Japan) whose extensometers perform with a high accuracy. The software then performs image processing of the data and calculates the elongation of the gauge length [9]. Maximum loads and maximum displacements were recorded by computer. All data were analyzed using SPSS v 15 for Windows (SPSS, Inc, Chicago, IL). The non-parametric Wilcoxon test was performed for statistical evaluation of the related groups. Differences were considered significant at $p<0.05$.

Results

Mean maximum load was measured as 2526.05 ± 218 Newton (N) in group I, 2505.92 ± 354 N in the control group, and 2481.18 ± 309 N in group II (Figure 4). The differences between

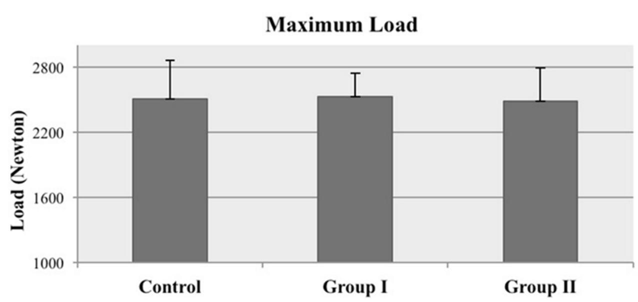

Figure 4. The maximum load of the groups

group I and the control group ($p=0.866$); group II and the control group ($p=1.00$); and group I and group II ($p=0,866$) were not statistically significant.

The mean stiffness values of the constructs subjected to deformity-causing loads were calculated. The highest rigidity was observed in the control group, which had a mean stiffness of 153.3 ± 32 N/mm. The mean stiffness was 145.8 ± 22 N/mm for group I and 151.4 ± 25 N/mm for group II (Figure 5). The

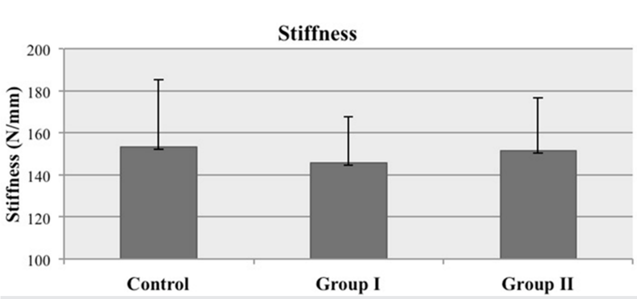

Figure 5. The stiffness graph of the groups. Stiffness was calculated with using the maximum load which considered the maximum load before the spicemens failured.

difference between group I and the control group ($p=0.735$); group II and the control group ($p=0.612$); and group I and group II ($p=0.499$) were not statistically significant. The results are given in Table 1.

Discussion

Adequate stabilization of proximal humerus fracture is important for early rehabilitation and successful results. Intramedullary fibular allografting of the humerus is a method to obtain better stabilized fracture construct, and it has been identified by Walch et al. for non-unions of the surgical neck of the humerus [10]. Medial column support is important to prevent varus collapse. Adequate mechanical support can be achieved by anatomic stable reduction with medial cortical contact or by placing an oblique medial support screw in the inferomedial portion of the proximal humerus [11]. Intramedullary fibular allograft restores the medial column and creates medial cortical support to prevent varus collapse [4,11].

Biomechanical performance of fibular allograft has been evaluated in several studies [12-15]. Mathison et al. studied 6 paired humeral specimens. One of each pair was repaired with locking plate fixation, and the other with locking plate plus fibular allograft [12]. Mathison demonstrated that the fibular allograft group increased the failure loads by 1.72 times and also increased initial stiffness by 3.84 times when compared with the control group [12]. Bae et al. showed that all maximum failure loads and stiffness values were significantly greater in the fibular allograft group [13]. Osterhoff et al. studied 20 composite analog osteoporotic humerus models [14]. They determined that the fibular allograft augmented fracture model showed 5 times lower intercyclic motion, 2 times lower fragment migration, and 2 times less residual plastic deformation [14]. Chow concluded that fibular allograft prevented collapse of the construct with repetitive varus loading, whereas 6 of 8 constructs without allograft collapsed [15]. All these studies were performed on a gap model simulating unstable fracture. Our study used a two-part fracture model with anatomic reduction of the medial cortex. We obtained similar results across all groups. Achieving anatomically stable reduction and absence of medial column comminution allows better maintenance of reduction [3]. Anatomical reduction of the medial cortex is important to, and sufficient for, stable fixation; augmentation is not necessary. Intramedullary fibula as a supplement to a locking plate can be used in fractures with medial comminution and/or poor bone quality [16].

When we evaluated ultimate load to failure and stiffness values, we obtained similar results across the two groups with fibular graft and the control group. We can conclude that neither the position nor the presence of fibular graft has a positive effect on anatomically reduced two-part proximal humeral fractures with a locking plate.

The limitation of this study is that cyclic loading is not performed.

In conclusion, if stable anatomical reduction is obtained in proximal humerus fractures, intramedullary fibular graft is not necessary. Fibular allograft is popular in proximal humeral fractures, but its usage must be limited to unstable osteoporotic fractures in which the medial column cannot be reduced.

Table 1. Demostrasting the initial stiffness, initial load, stiffness, maximum load and maximum displacement values of the groups.

Specimens	Initial Stiffness (N/mm)	Initial Load (N)	Stiffness (N/mm)	Max. Load (N)	Max. Displacement (mm)
Control Group	190.73 ± 79	465 ± 202	153.3 ± 32	2505.92 ± 354	16.89 ± 3.8
Group I	156.4 ± 47	510.02 ± 165	145.8 ± 22	2526.05 ± 218	17.59 ± 2.5
Group II	121.04 ± 24	244.55 ± 43	151.4 ± 25	2481.18 ± 309	16.58 ± 2.0

N: Newton

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Competing interests
The authors declare that they have no competing interests.

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